PJM Generator Interconnection
Q48 Calvert Cliffs 1640MW
Impact Study

September 2007

DMS #433706

Confidential

General

Queue Q48 is a Constellation Generation Group, LLC request to interconnect a 1640 MW (Net Capacity) Nuclear generating facility consisting of a single 1640 steam turbine generator. Project Q48 is located at 1650 Calvert Cliffs Parkway, Lusby, Calvert County, Maryland. Q48's proposed commercial date is 4Q 2015.

Direct Connection

The Q48 generation project can be interconnected as shown on the one line diagram below.

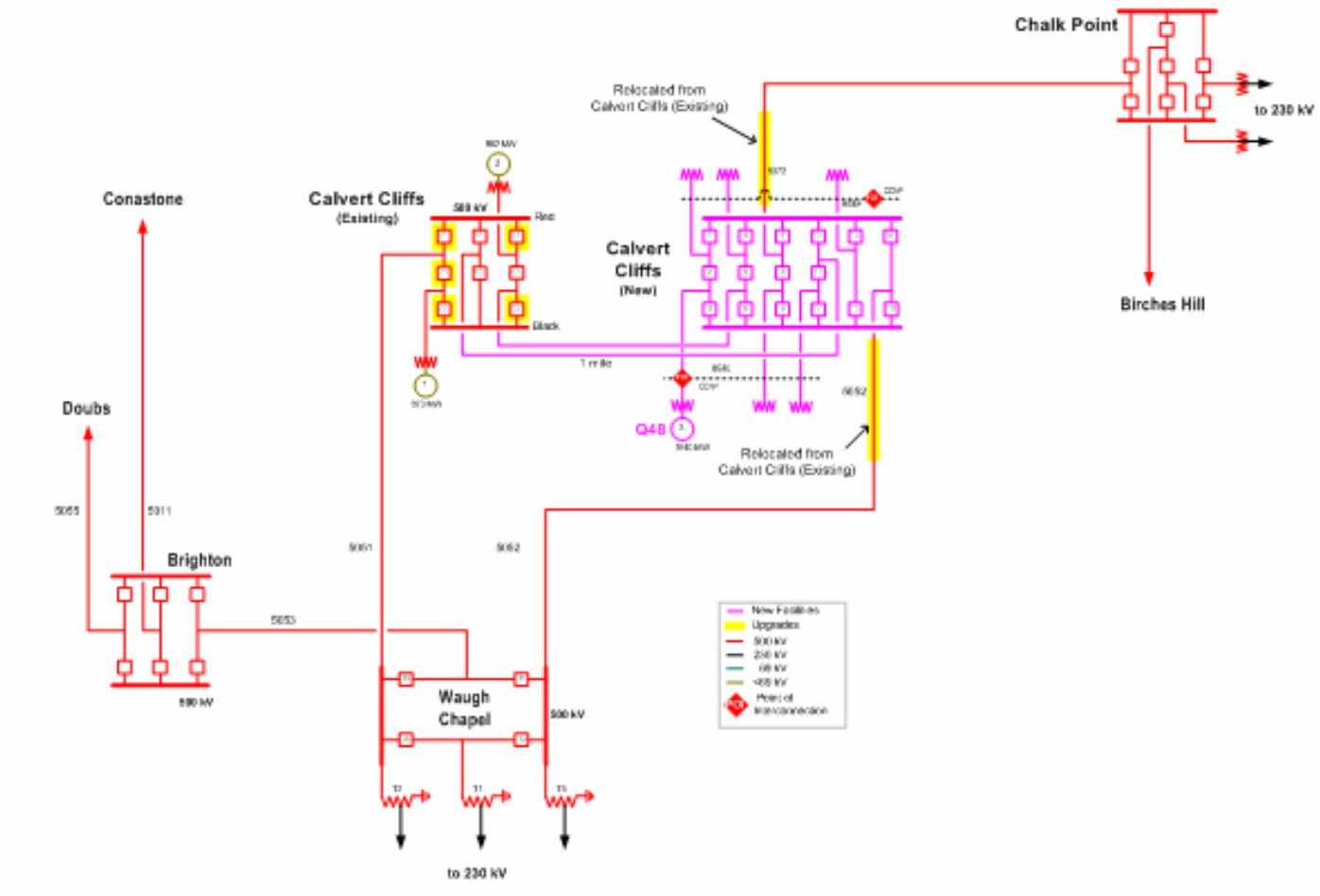


FIGURE 1

Interconnection Customer Scope of Work

Queue Q48 Interconnection Customer (IC) has assumed full responsibility for design and construction of all facilities associated with the Q48 generating station and other associated facilities on the IC side of the POI (Point of Interconnection). See Figure 1.

Baltimore Gas and Electric Company (BG&E) Scope of Direct Connection work

At Interconnection Customer expense BG&E will design, construct and own all Direct Connection Attachment Facilities on BG&E's side of the POI. The estimated cost and construction time is as follows:

$ 9,500,000	**Network Upgrade number n0751**. Construct two 1.0 mile 500 kV, 3500 MVA (normal rating) lines, on individual towers, to connect the existing Calvert Cliffs 500 kV station to the new Calvert Cliffs 500kV station.
$ 500,000	**Network Upgrade number n0752**. At Calvert Cliffs (Existing) Substation – upgrade two line positions previously used for 500 kV circuits 5052 and 5072 to now be used for two lines to the Calvert Cliffs (New) 500 kV station. Includes metering, relaying, communications, and other necessary facilities changes.
$ 49,000,000	**Network Upgrade number n0753** Construct one 500 kV, sixteen breaker, breaker and a half substation referred to as Calvert Cliffs (New) on FIGURE 1.
$ 59,000,000	**Total estimated Direct Connection Attachment Facilities cost**

The Direct Connection Attachment Facilities are estimated to take **36 to 48 months** to construct.

Network Impacts

The **#Q48 project was studied as an injection of 1640 MW (capacity) into the Calvert Cliffs 500 kV station.** Project #Q48 was evaluated for compliance with reliability criteria for summer peak conditions in 2011. Potential network impacts were as follows:

Stability Analysis

Stability analysis was performed at 2011 summer light load conditions. The maximum generation output is considered. The range of contingencies evaluated was limited to that necessary to assess expected compliance with MAAC criteria. **(Also see Attachment #3)**

Maintenance Outage	**Faulted Circuit**				
	1a	3a	4a	7a	3b
All facilites in service	Stable	Stable	Stable	Stable	Stable
Q1	Stable	Unstable (1435MW)	Stable	Stable	N/A
R1	Unstable (1435MW)	N/A	Unstable (1509MW)	Stable	N/A
P2	Stable	Unstable (1398MW)	N/A	Unstable (1473MW)	N/A
P3	Stable	Stable	Unstable* (1620MW)	N/A	N/A
Q2	Stable	Stable	Stable	Stable	N/A
Q3	Stable	Stable	Stable	Stable	N/A

To prevent the transient instability and voltage violations found with the criteria contingencies in the base case and all maintenance outage conditions, there are three optional solutions as follows:

Option I: Limit the output of the project under different maintenance outages. The numbers in the table show the limit of the project output to maintain the stability. However, it could change for different system operating conditions. **"Operating Guides" shall be required to address these reliability concerns. "Operating Guides" for Q48 generator will be developed during the Q48 Facilities Study if this option is chosen.**

Option II: The addition of two new transmission lines to allow for full output during maintenance outages:

1. Calvert Cliffs - Chalk Point 500kV * . **Network Upgrade number n0756.**
2. Waugh Chapel - Brighton 500kV * . **Network Upgrade number n0757.**

**** Note:*** *These transmission lines will be in parallel with the existing transmission lines between these same points. For the Q48 Impact Study the impedance used for the new line was the same as the existing parallel line, and a mutual coupling factor of 50% was assumed for the positive sequence and zero sequence power flow data.*

Option III: The addition of one 500 kV transmission line from Calvert Cliffs to Chalk Point (**Network Upgrade number n0758)**, and reducing the primary protective relay fault clearing time for relevant contingencies to 3.25 cycles or below (**Network Upgrade number n0758 for Protective Relay and Control Upgrades necessary to reduce clearing times)** may be a viable solution to allow for full output during maintenance outages of existing Calvert Cliffs 500 kV lines. **This option will need to be investigated further during the Q48 Facilities Study.**

Note: While the stability analysis has been performed at expected extreme system conditions, there is a potential that evaluation at a different level of generator MW and/or MVAR output at different system load levels and operating conditions would disclose unforeseen stability problems. The regional reliability analysis routinely performed to test all system changes will include one such evaluation. Any problems uncovered in that or other operating or planning studies will need to be resolved.

Moreover, when the proposed generating station is designed and plant specific dynamics data for the plant and its controls are available, and if it is different than the data provided for this study, a transient stability analysis at a variety of expected operating conditions using the more accurate data shall be performed to verify impact on the dynamic performance of the system. As more accurate or unit specific dynamics data for the proposed facility, as well as Plant layout become available, it must be forwarded to PJM.

Option I – No new 500 kV Lines

Generator Deliverability

(Single or N-1 contingencies for the Capacity portion of the interconnection)

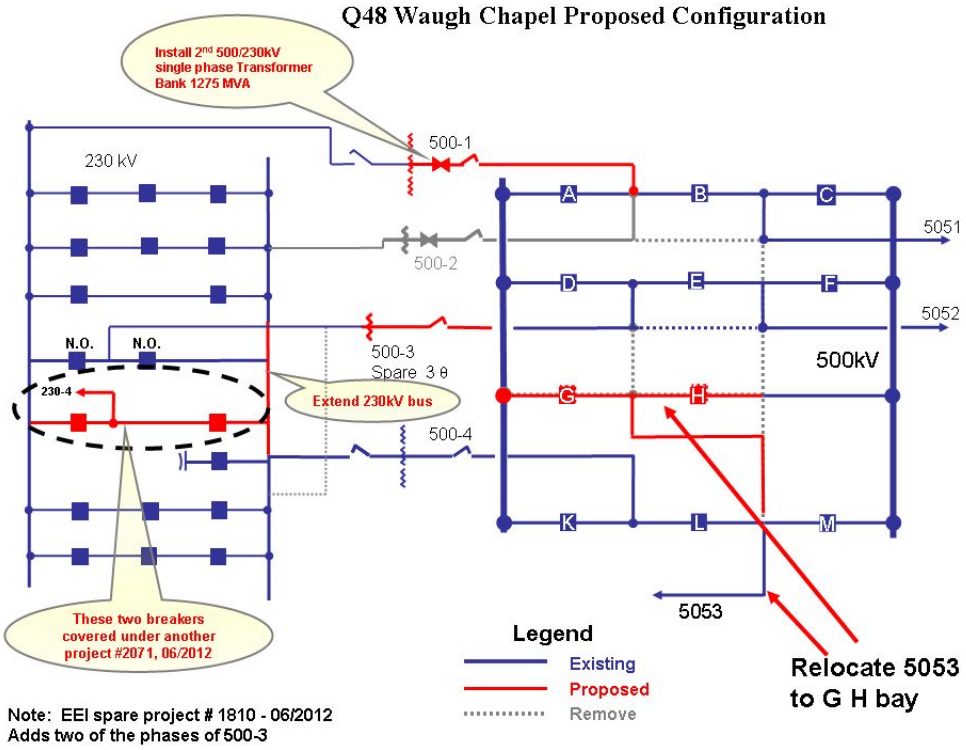
No Problems were identified

Multiple Facility Contingency

(Double Circuit Tower Line, Stuck breaker and bus fault contingencies)

1. **Network Upgrade number n0754.** The Waugh. Chapel 500/230kV transformer (ID #1) loads from 82.7% to 108.85% of its emergency rating (1630MVA) for a Waugh Chapel 500 kV line fault followed by a stuck breaker at Waugh Chapel. (CONTINGENCY WCHPL_L). Queue Q48 contributes approximately **474.2MW** to cause the thermal violation.

   Relocate Line 5053 to a bay with new breaker G and H. See the one line diagram below. The cost is **$7,400,000**. Estimated time to construct is **24 months.**



Short Circuit Analysis

See Attachment #1 for the Short Circuit Analysis results

Pepco Zone

- Short circuit analysis indicates a total of thirty six PEPCO 230 kV breakers are overdutied as a result of Q48 generation addition. 13 breakers are overdutied at Oak Grove 230 kV substation and will require replacement by 63 kA breakers (**Network Upgrade numbers n0759 to n0771)**, and 23 breakers at Chalk Point 230 kV substation are overdutied and will require replacement by 80 kA breakers (**Network Upgrade numbers n0772 to n0794).** Four of the 230 kV breakers at Chalk Point are owned by Mirant.

- Pepco's preliminary cost estimate to replace each of the 13 breakers at Oak Grove (**Network Upgrade numbers n0759 to n0771)** to 63 ka breakers is approximately $1.5 million, and the cost to replace each of the 23 breakers at Chalk Point (**Network Upgrade numbers n0772 to n0794)** to 80 ka breakers is $2.0 million for a total cost of **$65,500,000**.

- With Pepco's present capabilities, Pepco estimates the number of breakers that can be changed out in one year is approximately eight. (Work in Spring and Fall only), therefore the replacement of 36 breakers will take approximately **4-5 years**.

BG&E Zone

- Six BG&E 500 kV breakers at Calvert Cliff (Existing) station (**Network Upgrade numbers n0795 to n0800)** were determined to be overdutied as a result of Q48 generation addition.

- Calvert Cliff (Existing) station 500 kV breakers 21, 22, 41, 43, 61 and 62 can be upgraded by adding a TRV Capacitor kit at an estimated cost of **$1,795,200**. (**Network Upgrade numbers n0795 to n0800).**

- The Calvert Cliffs circuit breakers can be upgraded concurrently during an **18 month** timeframe.

Contribution to Previously Identified Overloads

(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

No problems were identified

Total Network Upgrade Cost Estimate for Option I is $74,695,200.

Option II – Add two new 500 kV lines

1. (**Network Upgrade number n0756**). REQUIRED TO SATISFY STABILITY SOLUTION OPTION #2 TO OPERATE AT 100% FOR THE OUTAGE OF ONE OF THE EXISTING CALVERT CLIFFS 500 kV LINES.

   Add a second Calvert Cliffs to Chalk Point 500 kV circuit.

   BG&E Section - 10 miles.

   $35,600,000 Estimated cost of new line.
   $ 7,400,000 Estimated cost to add 2 new 500 kV breaker at Calvert Cliffs.

   Estimated time to construct **60 months.**

   Pepco Section – 10 miles.

   $38,000,000 Estimated cost of new line.
   Assumes building a new DCTL (Double Circuit Tower Line) for existing and new circuits.

   $10,000,000 Estimated cost to add 2 new 500 kV breaker at Chalk Point.

   Estimated time to construct **60 months.**

2. (**Network Upgrade number n0757**). REQUIRED TO SATISFY STABILITY SOLUTION OPTION #2 TO OPERATE AT 100% FOR THE OUTAGE OF ONE OF THE EXISTING CALVERT CLIFFS 500 kV LINES.

   Add a second Waugh Chapel to Brighton 500 kV circuit.

   BG&E Section – 17 miles.

   $66,000,000 Estimated cost of new line.
   $ 7,400,000 Estimated cost to add 2 new 500 kV breakers at Waugh Chapel.

   Estimated time to construct **72 months.**

   Pepco Section - 10 miles.

   $52,800,000 Estimated cost of new line.
   Assumes building a new DCTL (Double Circuit Tower Line) for existing and new circuits, and also reconstructing two 230kV DCTLs to allow room for the 500kV circuits

   $10,000,000 Estimated cost to add 2 new 500 kV breakers at Brighton.

   Estimated time to construct **66 months.**

Generator Deliverability

(Single or N-1 contingencies for the Capacity portion of the interconnection)

No Problems were identified

Multiple Facility Contingency

(Double Circuit Tower Line, Stuck breaker and bus fault contingencies)

No Problems were identified

Short Circuit Analysis

OPTION II NETWORK UPGRADE REQUIREMENT IS THE SAME 42 BREAKER UPGRADES AS OPTION I PLUS UPGRADE OF TWO ADDITIONAL CALVERT CLIFFS 500 KV BREAKERS #23 AND #63 (**Network Upgrade numbers n0795 to n800, and n0801 and n0802)**.

Estimated cost **$67,893,600**. Estimated time to construct is the same **4-5 years for PEPCO breaker replacements** and **18 months for BG&E breaker replacements**.

Contribution to Previously Identified Overloads

(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

No problems were identified

Total Network Upgrade Cost Estimate for Option II is $297,486,600.

Option III – Add One 500 kV Line and Reduce Clearing Times to 3.25 Cycles or Less

(If Option #3 is a viable solution. Solution viability will be determined during the Q48 Facilities Study)

1. (**Network Upgrade number n0756**). REQUIRED TO SATISFY OPTION III TO OPERATE AT 100% FOR THE OUTAGE OF ONE OF THE EXISTING CALVERT CLIFFS 500 kV LINES.

   Add a second Calvert Cliffs to Chalk Point 500 kV circuit.

   BG&E Section - 10 miles.

$35,600,000	Estimated cost of new line**.**
$ 7,400,000	Estimated cost to add 2 new 500 kV breaker at Calvert Cliffs.
	Estimated time to construct **60 months.**

   Pepco Section – 10 miles.

$38,000,000	Estimated cost of new line**.** **Assumes** building a new DCTL (Double Circuit Tower Line) for existing and new circuits.
$10,000,000	Estimated cost to add 2 new 500 kV breaker at Chalk Point.
	Estimated time to construct **60 months.**

2. (**Network Upgrade number n0758**). REQUIRED TO SATISFY OPTION III TO OPERATE AT 100% FOR THE OUTAGE OF ONE OF THE EXISTING CALVERT CLIFFS 500 kV LINES.

   Relay protection system and control upgrades necessary to provide 3.25 cycle or less clearing times for relevant contingencies.

   The estimated cost is **$400,000** and the time to construct is **24 months**.

Generator Deliverability

(Single or N-1 contingencies for the Capacity portion of the interconnection)

No Problems were identified

Multiple Facility Contingency

(Double Circuit Tower Line, Stuck breaker and bus fault contingencies)

3. (**Network Upgrade number n0754).** The Waugh Chapel 500/230kV transformer (ID #1) loads from 81.4% to 103.71% of its emergency rating (1630MVA) for a Waugh Chapel 500 kV line fault followed by a stuck breaker at Waugh Chapel station (CONTINGENCY WCHPL_L). **This is a smaller overload than the 108.85% overload for Option I without any new 500 kV lines, but it remains an overload violation.** Queue Q48 contributes approximately **411.6MW** to cause the thermal violation.

   THE NETWORK UPGRADE REQUIREMENT IS THE SAME AS OPTION I.

   Estimated cost **$7,400,000**. Estimated time to construct **24 months**.

Short Circuit Analysis

See Attachment #1 for details.

THE NETWORK UPGRADE REQUIREMENT IS THE SAME 42 BREAKER UPGRADES AS OPTION I PLUS UPGRRADE OF TWO ADDITIONAL CALVERT CLIFFS 500 KV BREAKERS #23 AND #63 (**Network Upgrade numbers n0801 and n0802)**.

Estimated cost **$67,893,600**. Estimated time to construct is the same **4-5 years for PEPCO breaker replacements** and **18 months for BG&E breaker replacements**.

Contribution to Previously Identified Overloads

(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

No problems were identified

Total Network Upgrade Cost Estimate for Option III is $106,693,000.

ATTACHMENT #1

(Q48 Short Circuit Analysis and Breaker Upgrade Requirement Details)

Stability Solution Option #1

(No new 500 kV lines added)

Network Upgrade Number	Station	Voltage	T.O.	Breaker	Int Rating (A)	Rating Basis	Calculation Method	Calculated Short Circuit Current				Upgrade Cost	Upgrade Type
								Before Q48		After Q48			
								3-Phase	Ph-Gnd	3-Phase	Ph-Gnd		
n0759	Oak Grove	230kV	PEPCO	2B	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0760	Oak Grove	230kV	PEPCO	4A	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0761	Oak Grove	230kV	PEPCO	6A	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
no762	Oak Grove	230kV	PEPCO	6C	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0763	Oak Grove	230kV	PEPCO	7A	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0764	Oak Grove	230kV	PEPCO	7C	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0765	Oak Grove	230kV	PEPCO	9A	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0766	Oak Grove	230kV	PEPCO	9B	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0767	Oak Grove	230kV	PEPCO	9C	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0768	Oak Grove	230kV	PEPCO	10A	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0769	Oak Grove	230kV	PEPCO	10C	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0770	Oak Grove	230kV	PEPCO	13A	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0771	Oak Grove	230kV	PEPCO	13B	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breaker
n0772	Chalk Point	230kV	PEPCO	1A	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0773	Chalk Point	230kV	PEPCO	1B	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0774	Chalk Point	230kV	PEPCO	2A	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0775	Chalk Point	230kV	PEPCO	2B	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0776	Chalk Point	230kV	PEPCO	2C	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0777	Chalk Point	230kV	PEPCO	3A	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0778	Chalk Point	230kV	PEPCO	3B	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0779	Chalk Point	230kV	PEPCO	3C	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0780	Chalk Point	230kV	PEPCO	4A	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0781	Chalk Point	230kV	PEPCO	4B	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0782	Chalk Point	230kV	PEPCO	5A	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0783	Chalk Point	230kV	PEPCO	5B	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0784	Chalk Point	230kV	PEPCO	6A	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0785	Chalk Point	230kV	PEPCO	6B	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker
n0786	Chalk Point	230kV	PEPCO	7B	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breaker

Network Upgrade Number	Station	Voltage	T.O.	Breaker	Int Rating (A	Rating Basis	Calculation Method	Calculated Short Circuit Current				Upgrade Cost	Upgrade Type
								Before Q48		After Q48			
								3-Phase	Ph-Gnd	3-Phase	Ph-Gnd		
n0787	Chalk Point	230kV	PEPCO	8A	45243.5	Symm	IEEE C37.010	45216	38504	45629	38751	$1,500,000	Replace with 63kA breake
n0788	Chalk Point	230kV	PEPCO	8B	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breake
n0789	Chalk Point	230kV	PEPCO	7A	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breake
n0790	Chalk Point	230kV	PEPCO	1C	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breake
n0791	Chalk Point	230kV	Mirant	4C	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breake
n0792	Chalk Point	230kV	Mirant	5C	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breake
n0793	Chalk Point	230kV	Mirant	6C	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breake
n0794	Chalk Point	230kV	Mirant	7C	63000	Symm	IEEE C37.010	62438	62210	63452	62970	$2,000,000	Replace with 80kA breake
n0795	Calvert Cliffs	500kV	BG&E	21	50699.4	Total I	IEEE C37.5	38046	38947	46915	53325	$299,200	Upgrade
n0796	Calvert Cliffs	500kV	BG&E	22	50699.4	Total I	IEEE C37.5	38046	38947	46915	53325	$299,200	Upgrade
n0797	Calvert Cliffs	500kV	BG&E	41	51999.6	Total I	IEEE C37.5	38046	38947	46915	53325	$299,200	Upgrade
n0798	Calvert Cliffs	500kV	BG&E	43	51999.6	Total I	IEEE C37.5	38046	38947	46915	53325	$299,200	Upgrade
n0799	Calvert Cliffs	500kV	BG&E	61	50699.4	Total I	IEEE C37.5	38046	38947	46915	53325	$299,200	Upgrade
n0800	Calvert Cliffs	500kV	BG&E	62	50699.4	Total I	IEEE C37.5	38046	38947	46915	53325	$299,200	Upgrade

Note 1 About 8 of 36 PEPCO breakers at Oak Grove and Chalk Point can be replaced per year. Total replacement time for 36 breakers is approximately 4 - 5 years.

Note 2 The 6 BG&E breakers at Calvert Cliffs can be upgraded concurrently in an 18 month timeframe

Stability Solution Option #2

(Two new 500 kV lines added)

Network Upgrade Number	Station	Voltage	T.O.	Breaker	Int Rating (A)	Rating Basis	Calculation Method	Calculated Short Circuit Current				Upgrade Cost	Upgrade Type
								Before Q48		After Q48			
								3-Phase	Ph-Gnd	3-Phase	Ph-Gnd		
n0759	Oak Grove	230kV	PEPCO	2B	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0760	Oak Grove	230kV	PEPCO	4A	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0761	Oak Grove	230kV	PEPCO	6A	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
no762	Oak Grove	230kV	PEPCO	6C	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0763	Oak Grove	230kV	PEPCO	7A	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0764	Oak Grove	230kV	PEPCO	7C	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0765	Oak Grove	230kV	PEPCO	9A	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0766	Oak Grove	230kV	PEPCO	9B	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0767	Oak Grove	230kV	PEPCO	9C	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0768	Oak Grove	230kV	PEPCO	10A	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0769	Oak Grove	230kV	PEPCO	10C	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0770	Oak Grove	230kV	PEPCO	13A	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0771	Oak Grove	230kV	PEPCO	13B	45243.5	Symm	IEEE C37.010	45216	38504	45743	38868	$1,500,000	Replace with 63kA breaker
n0772	Chalk Point	230kV	PEPCO	1A	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0773	Chalk Point	230kV	PEPCO	1B	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0774	Chalk Point	230kV	PEPCO	2A	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0775	Chalk Point	230kV	PEPCO	2B	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0776	Chalk Point	230kV	PEPCO	2C	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0777	Chalk Point	230kV	PEPCO	3A	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0778	Chalk Point	230kV	PEPCO	3B	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0779	Chalk Point	230kV	PEPCO	3C	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0780	Chalk Point	230kV	PEPCO	4A	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0781	Chalk Point	230kV	PEPCO	4B	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0782	Chalk Point	230kV	PEPCO	5A	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0783	Chalk Point	230kV	PEPCO	5B	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0784	Chalk Point	230kV	PEPCO	6A	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0785	Chalk Point	230kV	PEPCO	6B	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0786	Chalk Point	230kV	PEPCO	7B	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker

Network Upgrade Number	Station	Voltage	T.O.	Breaker	Int Rating (A)	Rating Basis	Calculation Method	Calculated Short Circuit Current				Upgrade Cost	Upgrade Type
								Before Q48		After Q48			
								3-Phase	Ph-Gnd	3-Phase	Ph-Gnd		
n0787	Chalk Point	230kV	PEPCO	8A	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0788	Chalk Point	230kV	PEPCO	8B	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0789	Chalk Point	230kV	PEPCO	7A	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0790	Chalk Point	230kV	PEPCO	1C	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0791	Chalk Point	230kV	Mirant	4C	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0792	Chalk Point	230kV	Mirant	5C	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0793	Chalk Point	230kV	Mirant	6C	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0794	Chalk Point	230kV	Mirant	7C	63000	Symm	IEEE C37.010	62438	62210	64191	64425	$2,000,000	Replace with 80kA breaker
n0795	Calvert Cliffs	500kV	BG&E	21	50699.4	Total I	IEEE C37.5	38046	38947	50154	57162	$299,200	Upgrade
n0796	Calvert Cliffs	500kV	BG&E	22	50699.4	Total I	IEEE C37.5	38046	38947	50154	57162	$299,200	Upgrade
n0797	Calvert Cliffs	500kV	BG&E	41	50699.4	Total I	IEEE C37.5	34437	36045	46176	53454	$299,200	Upgrade
n0798	Calvert Cliffs	500kV	BG&E	43	51999.6	Total I	IEEE C37.5	38046	38947	50154	57162	$299,200	Upgrade
n0799	Calvert Cliffs	500kV	BG&E	61	51999.6	Total I	IEEE C37.5	38046	38947	50154	57162	$299,200	Upgrade
n0800	Calvert Cliffs	500kV	BG&E	62	50699.4	Total I	IEEE C37.5	38046	38947	50154	57162	$299,200	Upgrade
n0801	Calvert Cliffs	500kV	BG&E	23	50699.4	Total I	IEEE C37.5	38046	38947	50154	57162	$299,200	Upgrade
n0802	Calvert Cliffs	500kV	BG&E	63	50699.4	Total I	IEEE C37.5	33830	31868	46625	53276	$299,200	Upgrade

Note 1 About 8 of 36 PEPCO breakers at Oak Grove and Chalk Point can be replaced per year. Total replacement time for 36 breakers is approximately 4 - 5 years.

Note 3 8 BG&E breakers at Calvert Cliffs can be upgraded concurrently in an 18 month timeframe.

Stability Solution Option #3

(One new 500 kV line added)

Network Upgrade Number	Station	Voltage	T.O.	Breaker	Int Rating (A)	Rating Basis	Calculation Method	Calculated Short Circuit Current				Upgrade Cost	Upgrade Type
								Before Q48		After Q48			
								3-Phase	Ph-Gnd	3-Phase	Ph-Gnd		
n0759	Oak Grove	230kV	PEPCO	2B	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0760	Oak Grove	230kV	PEPCO	4A	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0761	Oak Grove	230kV	PEPCO	6A	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
no762	Oak Grove	230kV	PEPCO	6C	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0763	Oak Grove	230kV	PEPCO	7A	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0764	Oak Grove	230kV	PEPCO	7C	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0765	Oak Grove	230kV	PEPCO	9A	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0766	Oak Grove	230kV	PEPCO	9B	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0767	Oak Grove	230kV	PEPCO	9C	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0768	Oak Grove	230kV	PEPCO	10A	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0769	Oak Grove	230kV	PEPCO	10C	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0770	Oak Grove	230kV	PEPCO	13A	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0771	Oak Grove	230kV	PEPCO	13B	45243.5	Symm	IEEE C37.010	45216	38504	45731	38861	$1,500,000	Replace with 63kA breaker
n0772	Chalk Point	230kV	PEPCO	1A	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0773	Chalk Point	230kV	PEPCO	1B	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0774	Chalk Point	230kV	PEPCO	2A	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0775	Chalk Point	230kV	PEPCO	2B	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0776	Chalk Point	230kV	PEPCO	2C	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0777	Chalk Point	230kV	PEPCO	3A	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0778	Chalk Point	230kV	PEPCO	3B	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0779	Chalk Point	230kV	PEPCO	3C	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0780	Chalk Point	230kV	PEPCO	4A	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0781	Chalk Point	230kV	PEPCO	4B	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0782	Chalk Point	230kV	PEPCO	5A	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0783	Chalk Point	230kV	PEPCO	5B	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0784	Chalk Point	230kV	PEPCO	6A	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0785	Chalk Point	230kV	PEPCO	6B	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0786	Chalk Point	230kV	PEPCO	7B	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker

Network Upgrade Number	Station	Voltage	T.O.	Breaker	Int Rating (A)	Rating Basis	Calculation Method	Calculated Short Circuit Current				Upgrade Cost	Upgrade Type
								Before Q48		After Q48			
								3-Phase	Ph-Gnd	3-Phase	Ph-Gnd		
n0787	Chalk Point	230kV	PEPCO	8A	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n07888	Chalk Point	230kV	PEPCO	8B	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0789	Chalk Point	230kV	PEPCO	7A	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0790	Chalk Point	230kV	PEPCO	1C	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0791	Chalk Point	230kV	Mirant	4C	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0792	Chalk Point	230kV	Mirant	5C	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0793	Chalk Point	230kV	Mirant	6C	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0794	Chalk Point	230kV	Mirant	7C	63000	Symm	IEEE C37.010	62438	62210	64080	64346	$2,000,000	Replace with 80kA breaker
n0795	Calvert Cliffs	500kV	BG&E	21	50699.4	Total I	IEEE C37.5	38046	38947	49104	56198	$299,200	Upgrade
n0796	Calvert Cliffs	500kV	BG&E	22	50699.4	Total I	IEEE C37.5	38046	38947	49104	56198	$299,200	Upgrade
n0797	Calvert Cliffs	500kV	BG&E	41	50699.4	Total I	IEEE C37.5	34437	36045	45680	52981	$299,200	Upgrade
n0798	Calvert Cliffs	500kV	BG&E	43	51999.6	Total I	IEEE C37.5	38046	38947	49104	56198	$299,200	Upgrade
n0799	Calvert Cliffs	500kV	BG&E	61	51999.6	Total I	IEEE C37.5	38046	38947	49104	56198	$299,200	Upgrade
n0800	Calvert Cliffs	500kV	BG&E	62	50699.4	Total I	IEEE C37.5	38046	38947	49104	56198	$299,200	Upgrade
n0801	Calvert Cliffs	500kV	BG&E	23	50699.4	Total I	IEEE C37.5	38046	38947	49104	56198	$299,200	Upgrade
n0802	Calvert Cliffs	500kV	BG&E	63	50699.4	Total I	IEEE C37.5	33830	31868	45554	52280	$299,200	Upgrade

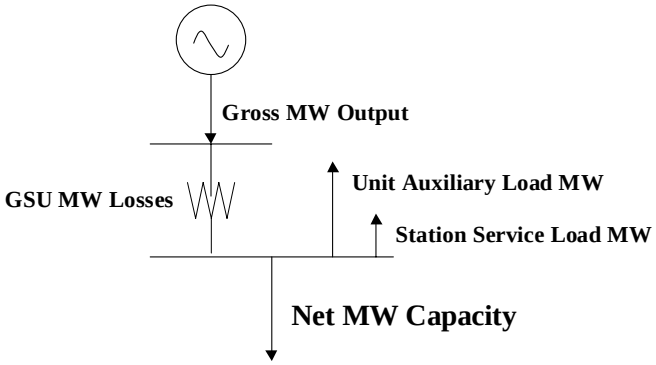
Note 1 About 8 of 36 PEPCO breakers at Oak Grove and Chalk Point can be replaced per year. Total replacement time for 36 breakers is approximately 4 - 5 years.

Note 3 8 BG&E breakers at Calvert Cliffs can be upgraded concurrently in an 18 month timeframe

ATTACHMENT #2

(Q48 Generator and GSU Data)

Unit Capability Data



Net MW Capacity = (Gross MW Output - GSU MW Losses* – Unit Auxiliary Load MW - Station Service Load MW)

Queue Letter/Position/Unit ID: _____ Q48

Primary Fuel Type: _____Nuclear

Maximum Summer (92º F ambient air temp.) Net MW Output**:_____ 1640

Maximum Summer (92º F ambient air temp.) Gross MW Output: _____ 1696

Minimum Summer (92º F ambient air temp.) Gross MW Output: _____ 339

Maximum Winter (30º F ambient air temp.) Gross MW Output: _____ 1768

Minimum Winter (30º F ambient air temp.) Gross MW Output: _____ 353

Gross Reactive Power Capability at Maximum Gross MW Output – Please include Reactive Capability Curve (Leading and Lagging):_____ [-700, 900]

Individual Unit Auxiliary Load at Maximum Summer MW Output (MW/MVAR): ___ 56

Individual Unit Auxiliary Load at Minimum Summer MW Output (MW/MVAR): __ n/a

Individual Unit Auxiliary Load at Maximum Winter MW Output (MW/MVAR): ___ 128

Individual Unit Auxiliary Load at Minimum Winter MW Output (MW/MVAR): ___ n/a

Station Service Load (MW/MVAR):_____ n/a

* GSU losses are expected to be minimal.
** Your project's declared MW, as first submitted in Attachment N, and later confirmed or modified by the Impact Study Agreement, should be based on either the 92º F Ambient Air Temperature rating of the unit(s) or, if less, the declared Capacity rating of your project.

Unit Generator Dynamics Data

Queue Letter/Position/Unit ID: _____ Q48

MVA Base (upon which all reactances, resistance and inertia are calculated): _____ 2015

Nominal Power Factor: _____ 0.9

Terminal Voltage (kV): _____ 27

Unsaturated Reactances **(on MVA Base)**

- Direct Axis Synchronous Reactance, $X_{d(i)}$: _____ 2.2779
- Direct Axis Transient Reactance, X'd(i): _____ 0.5469
- Direct Axis Sub-transient Reactance, X"d(i): _____ 0.3791
- Quadrature Axis Synchronous Reactance, Xq(i): _____ 2.2023
- Quadrature Axis Transient Reactance, X'q(i): _____ 1.0935
- Quadrature Axis Sub-transient Reactance, X"q(i): _____ 0.4131
- Stator Leakage Reactance, Xl: _____ 0.3167
- Negative Sequence Reactance, X2(i): _____ 0.3961
- Zero Sequence Reactance, X0: _____ 0.2288

Saturated Sub-transient Reactance, X"d(v) (on MVA Base): _____ 0.3066

Armature Resistance, Ra (on MVA Base): _____ 0.0008

Time Constants (seconds)

- Direct Axis Transient Open Circuit, T'_{do}: _____ 8.198
- Direct Axis Sub-transient Open Circuit, $T"_{do}$: _____ 0.056
- Quadrature Axis Transient Open Circuit, T'_{qo}: _____ 0.911
- Quadrature Axis Sub-transient Open Circuit, $T"_{qo}$: _____ 0.103
- Inertia, H (kW-sec/kVA, on KVA Base): _____ 3.66

Speed Damping, D: _____ 4

Saturation Values at Per-Unit Voltage [S(1.0), S(1.2)]: _____ [0.19,0.68]

Units utilize a *Generator model*

Unit GSU Data

Queue Letter/Position/Unit ID: _____ Q48

Generator Step-up Transformer MVA Base:_____ 2130

Generator Step-up Transformer Impedance (R+jX, or %, on transformer MVA Base):0.2113+j9.9978

Generator Step-up Transformer Reactance-to-Resistance Ration (X/R): _____ n/a

Generator Step-up Transformer Rating (MVA): _____ 2130

Generator Step-up Transformer Low-side Voltage (kV): _____ 27

Generator Step-up Transformer High-side Voltage (kV):_____ 500

Generator Step-up Transformer Off-nominal Turns Ratio:_____ n/a

Generator Step-up Transformer Number of Taps and Step Size:LTC with 30 taps@1% each

ATTACHMENT #3

(Q48 Stability Analysis Contingencies Tested and Results)

Q48
2011 Light Load Stability Faults

BREAKER CLEARING TIMES (CYCLES)

Station	Primary (3ph/slg)	Stuck Breaker (total)	Zone 2 (total)
All 500kV	4.5	13	-
All 230kV	4.5	15	34

Q48-1a 3ph fault @ Calvert Cliffs 500kV on Calvert Cliffs-Waugh Chapel 500kV no.1
Q48-1b slg fault @ Calvert Cliffs 500kV on Calvert Cliffs-Waugh Chapel 500kV no.1, BF @ Calvert Cliffs 500kV, l/o Calvert Cliffs load 2
Q48-3a 3ph fault @ Calvert Cliffs 500kV on Calvert Cliffs-Chalk Point 500kV
Q48-3b slg fault @ Calvert Cliffs 500kV on Calvert Cliffs-Chalk Point 500kV, BF @ Calvert Cliffs 500kV, no additional element lost
Q48-4a 3ph fault @ Waugh Chapel 500kV on Waugh Chapel-Brighton 500kV
Q48-4b slg fault @ Waugh Chapel 500kV on Waugh Chapel-Brighton 500kV, BF @ Waugh Chapel 500kV breaker L, l/o Waugh Chapel 500/230 kV transformer 4 and Waugh Chapel 230kV capacitor
Q48-5a 3ph fault @ Waugh Chapel 500kV on Waugh Chapel 500/230 kV transformer no. 1
Q48-5b1 slg fault @ Waugh Chapel 500kV on Waugh Chapel 500/230 kV transformer no.1, BF@ Waugh Chapel 500kV breaker B, l/o Waugh Chapel-Calvert Cliffs 500kV no. 1
Q48-5b2 slg fault @ Waugh Chapel 500kV on Waugh Chapel 500/230 kV transformer no. 4, BF @ Waugh Chapel 500kV breaker L, l/o Waugh Chapel-Brighton 500kV
Q48-7a 3ph fault @ Chalk Point 500kV on Chalk Point-Burches Hill-Possum Pt 500kV
Q48-7b slg @ Chalk Point 500kV on Chalk Point-Burches Hill-Possum Pt 500kV, BF @ Chalk Point 500kV, l/o Chalk Point 500/230kV transformer no. 1
Q48-8a 3ph fault @ Chalk Point 500kV on Chalk Point 500/230kV transformer no. 1
Q48-8b slg fault @ Chalk Point 500kV on Chalk Point 500/230kV transformer no. 1, BF @ Chalk Point 500kV, l/o Chalk Point-Burches Hill-Possum Pt. 500kV
Q48-9a 3ph fault @ Waugh Chapel 230kV on Waugh Chapel-Brandon Shores 230kV no. 1
Q48-9b1 slg fault @ Waugh Chapel 230kV on Waugh Chapel-Brandon Shores 230kV no. 1, BF @ Waugh Chapel, l/o Waugh Chapel 500/230 kV transformer no. 4 and Waugh Chapel 230kV capacitor
Q48-9b2 slg fault @ Waugh Chapel 230kV on Waugh Chapel-Brandon Shores 230kV no. 1, BF @ Waugh Chapel, l/o Waugh Chapel 230/115 kV transformer no. 1
Q48-9c slg @ 80% of Waugh Chapel-Brandon Shores 230kV no. 1, zone 2 clearing from Waugh Chapel
Q48-10a 3ph fault @ Waugh Chapel 230kV on Waugh Chapel-High Ridge 230kV no. 1
Q48-10b1 slg fault @ Waugh Chapel 230kV on Waugh Chapel-High Ridge 230kV no. 1, BF @ Waugh Chapel 230kV, l/o Waugh Chapel 500/230 kV transformer no. 4 and Waugh Chapel 230kV capacitor
Q48-10b2 slg fault @ Waugh Chapel 230kV on Waugh Chapel-High Ridge 230kV no. 1, BF @ Waugh Chapel 230kV, l/o Waugh Chapel 230/115 kV transformer no. 2
Q48-10b3 slg fault @ Waugh Chapel 230kV on Waugh Chapel-High Ridge 230kV no. 2, BF @ Waugh Chapel 230kV, l/o Waugh Chapel-Jericho Park-Bowie 230kV no. 2
Q48-10c slg @ 80% of Waugh Chapel-High Ridge 230kV no. 1, zone 2 clearing from Waugh Chapel

Q48-11a 3ph fault @ Waugh Chapel 230kV on Waugh Chapel-Jericho Park-Bowie 230kV no. 1
Q48-11b1 slg fault @ Waugh Chapel 230kV on Waugh Chapel-Jericho Park-Bowie 230kV no. 1, BF @ Waugh Chapel 230kV, l/o Waugh Chapel 500/230kV transformer no. 1
Q48-11b2 slg fault @ Waugh Chapel 230kV on Waugh Chapel-Jericho Park-Bowie 230kV no. 1, BF @ Waugh Chapel 230kV, l/o Waugh Chapel 500/230kV transformer no. 4 and Waugh Chapel 230kV capacitor
Q48-11b3 slg fault @ Waugh Chapel 230kV on Waugh Chapel-Jericho Park-Bowie 230kV no. 2, BF @ Waugh Chapel 230kV, l/o Waugh Chapel-High Ridge 230kV no. 2
Q48-11c slg @ 80% of Waugh Chapel-Jericho Park-Bowie 230kV no. 1, zone 2 clearing from Waugh Chapel
Q48-12a 3ph fault @ Waugh Chapel 230kV on Waugh Chapel 230/115kV no. 1
Q48-12b1 slg fault @ Waugh Chapel 230kV on Waugh Chapel 230/115kV no. 1, BF @ Waugh Chapel 230kV, l/o Waugh Chapel 500/230 kV transformer no. 1
Q48-12b2 slg fault @ Waugh Chapel 230kV on Waugh Chapel 230/115kV no. 1, BF @ Waugh Chapel 230kV, l/o Waugh Chapel-Brandon Shores 230kV no.1
Q48-12b3 slg fault @ Waugh Chapel 230kV on Waugh Chapel 230/115kV no. 2, BF @ Waugh Chapel 230kV, l/o Waugh Chapel-High Ridge 230kV no.1

NETWORK CONDITIONS

1. Case b: All facilities in service (base case)
2. Case q1: Calvert Cliffs-Waugh Chapel 500kV no.2 outage
3. Case r1: Calvert Cliffs-Chalk Point 500kV outage
4. Case p2: Waugh Chapel-Brighton 500kV outage
5. Case q2: Waugh Chapel 500/230kV no.2 transformer outage
6. Case p3: Chalk Point -Burches Hill-Possum Pt. 500kV outage
7. Case q3: Chalk Point 500/230kV transformer no.2 outage
8. Case p4: Waugh Chapel-Brandon Shores 230kV no. 2 outage
9. Case q4: Waugh Chapel-High Ridge 230kV no.2 outage
10. Case r4: Waugh Chapel-Jericho Park-Bowie 230kV no.2 outage
11. Case s4: Waugh Chapel 230kV/115kV no. 2 transformer outage

For the other 10 N-1 network conditions, only 3-phase fault contingencies were considered